ТЕХНІЧНІ НАУКИ

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INCREASING THE WEAR RESISTANCE OF THE WORKING BODIES OF TILLAGE MACHINES BY ELECTRICAL DISCHARGE MACHINING

Abstract

In this work, the effective technological parameters of electrical discharge machining for increasing the wear resistance of steels operating under abrasive wear conditions were determined. It has been established that the optimal technological parameters of electrical discharge machining are as follows: current 350–450 A, voltage 45 V, temperature of the working environment 30–40 °C. According to the results of the studies, it was found that the most significant effect on the wear resistance of the treated surface is the current strength, since it affects the quality of the surface layer melting and the depth of processing. Another significant factor is the temperature of the dielectric cooling medium: with an increase in the temperature of the cooling medium, the surface cooling rate cannot meet the conditions (200 °C/s) for the formation of martensitic structures, and with a decrease in temperature, internal stresses occur in the hardened surface, which lead to the formation of microcracks. As a result of electrical discharge machining, the microhardness of the treated layer increases for X12 steel within 12–12,8 GPa, for 65Г steel within 10,5–11,2 GPa, and for 45 steel within 7,3–8,2 GPa. The hardness increase is due to the formation of a fine-needle martensite structure and alloying of the surface layer with Mn, Si, Ni and Cr.

It has been established that the use of electrical discharge machining increases the wear resistance of 65Г steel when operating on soils with different mechanical composition, abrasive properties, and various external factors by an average of 60–80%.

The use of electrical discharge machining to strengthen the working bodies of disc tillage tools made of 65Г steel allows to increase wear resistance in comparison with: serial ones – by 1,76 times, with the working surface strengthened by T-590 electrode – by 1,1 times, with the working bodies of Bellota (made of 28MnB5 steel) – by 1,16 times. In addition, during the operation of the working bodies hardened by electrical discharge machining, the effect of self-sharpening was observed, which in turn contributed to a decrease in traction resistance by 4–16% compared to the serial ones.

Key words: *steel, hardness, electrical discharge machining, wear resistance.*

Introduction. The world's food security largely depends on the efficiency of the agricultural sector, where mechanization of field work plays an important role [1]. Soil cultivation (plowing, cultivation, etc.) is one of the most energy-intensive stages that requires reliable and wear-resistant working parts of agricultural machinery. Components such as plow ploughshares, disk knives, and cultivator tines are subject to intense abrasive wear during operation due to contact with soil particles. This leads to a gradual loss of material, a deterioration in the quality of tillage, and increased fuel consumption and repair and maintenance costs. Studies have shown that wear is particularly accelerated when the coarse sand content in the soil is high. Therefore, increasing the wear resistance of tillage machines' working bodies is an urgent task, as it allows to extend their service life, reduce equipment downtime and increase the energy efficiency of agricultural production [4; 2; 7].

Materials science has developed a number of approaches to protecting parts from wear. Traditionally, wear-resistant steels or heat treatment (quenching) are used to harden the surface. In addition, hard coating technologies have become widespread – from surfacing of carbide layers to gas-thermal or diffusion application of ceramic and composite coatings [4; 7]. A properly selected coating can significantly reduce the wear of tillage tools in the abrasive environment of the soil [1]. At the same time, each of these methods has certain disadvantages. In particular, hardening increases hardness but can reduce the material's toughness, causing brittleness. Some modern methods of surface hardening (laser and plasma surfacing, detonation spraying, etc.) are effective against wear, but are accompanied by cracks in coatings, high energy consumption, and environmental risks [4]. This prompts researchers to look for alternative hardening technologies that will provide high hardness and wear resistance without these drawbacks [3].

One of the most promising areas is the electrical discharge machining of metal surfaces (electrospark alloying). This method involves the pulsed transmission of an electric discharge between an electrode and a workpiece, which causes the electrode material to melt for a short time and be applied to the surface of the workpiece in a thin layer. The resulting coating is metallurgically bonded to the substrate and has increased hardness due to the formed fine dendritic structure and the presence of solid phases (e.g., carbides) [1]. Unlike laser or plasma surfacing, which are characterized by high energy concentration and can cause cracking, electric spark technology uses relatively low thermal impact and is much more economical, which makes it attractive for use in agricultural engineering [1]. The presence of a hardened layer on the surface allows combining high surface hardness with the toughness and strength of the base material of the part, which is especially important for tillage tools operating under severe conditions of impact and abrasive wear. Recent studies confirm the effectiveness of electrical discharge methods for increasing the wear resistance of agricultural implements. In particular, it was found that the electrospark application of a special alloy (grade D517) to 65Г steel forms a fine dendritic structure with carbide inclusions, which reduces the rate of abrasive wear in model soil tests by about 16–21% compared to traditionally hardened steel [1]. These results indicate the significant potential of electrical discharge machining as a means of strengthening the working bodies of tillage machines. At the same time, further study of the material science aspects of this technology remains relevant, in particular, the effect of EDM alloying modes on the structure and properties of the material surface layer and, as a result, on its wear resistance. This issue is the subject of further research in this paper.

Research objective. The aim of the study is to determine the influence of electroerosion machining parameters on improving the wear resistance of working parts of soil cultivation machines by optimising machining modes and establishing the most effective technological parameters that ensure maximum increase in the service life of parts under operating conditions in an abrasive soil environment.

Presentation of the main research material. Increasing the wear resistance of machine parts is possible by the following methods: structural; technological; operational [5–7].

The design possibilities for increasing the wear resistance of machine parts are quite diverse, but they all boil down mainly to improving the operating conditions of the parts (eliminating external friction, improving friction conditions, etc.).

Operational methods for increasing wear resistance include optimizing operating modes, timely maintenance and repair of friction units, etc.

The most significant increase in the wear resistance of parts operating in an abrasive mass is possible by the technological methods shown in Fig. 1 [5–7; 9].

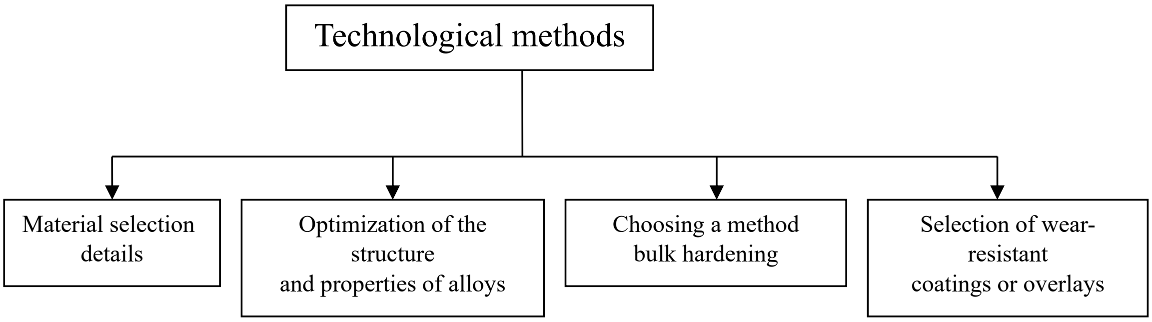


Fig. 1. Technological methods of increasing the wear resistance of parts

The choice of material should be made depending on the operating conditions of the part – stress state, external friction conditions, temperature conditions, and environmental properties [8].

The technical requirements for tillage machine disks for domestic equipment stipulate that they should be made of 65Г steel or its substitute, M76 steel and 45 steel with a heat treatment for a hardness of 39–44 HRC. Disks from foreign manufacturers are made of more wear-resistant steels, including 28 MnB5 steel from Bellota and Earth Metal from Case. The steel sheet used to make these wheels is rolled in two perpendicular directions, and the wheels are subject to complex heat and shot blasting treatment. The cost of such disks is 2,0–2,3 times higher than the cost of domestic disks and has 20–30% higher wear resistance [8]. The use of high-quality metals and alloys is economically impractical, so the solution should be sought in the use of methods of local hardening of working surfaces.

The following types of surfacing are used for the working bodies of machines operating in abrasive mass: manual gas bar surfacing with Sormite № 1; arc powder tape surfacing; multi-electrode electroslag surfacing; plasma surfacing; induction surfacing.

In agricultural engineering, 90% of all hardening work is done by induction surfacing [8]. The main disadvantage of this method is the high cost of surfacing alloys.

To increase the wear resistance of disk implements, the working surface is subjected to volumetric heat treatment. When choosing a heat treatment for steel, it is necessary to be guided by obtaining the highest hardness with sufficient toughness (depending on the strength conditions). It is also necessary to take into account the most rational steel structure for abrasive wear.

In the process of impact abrasion, the wear resistance of carbon steels depends not only on hardness but also on the composition and structure of the steel. Steels with a carbon content of about 0,7% have the highest wear resistance. Steels with a higher carbon content have lower wear resistance due to brittle decomposition. With a carbon content of less than 0,7%, steels undergo plastic deformation and wear more [7].

In the work of A.I. Sidashenko [10], it is recommended to surfacing the working edge with a T-590 electrode, 4 mm in diameter, with a welding current of 260–280 A from the outside at a distance of 1–5 mm from the edge of the disk. As a result of the operation of such disks, an increase in durability by 2,5–3,5 times compared to serial ones and an improvement in the process of self-sharpening were observed.

Recently, the method of metal EDM has become increasingly widespread. EDM is included in modern technologies as one of the most promising ways to manufacture and process parts made of difficult-to-machine materials, which will reduce the labor intensity and cost of manufacturing and processing processes.

The first to describe the process of metal erosion under the action of electric current was the English scientist J. Priestley (late eighteenth century). The first electrical discharge unit was created by Soviet scientists B.R. Lazarenko and N.I. Lazarenko (1943) [8].

EDM is a change in the shape, size, roughness and surface properties of workpieces under the influence of electrical discharges as a result of electrical erosion.

Such processing is characterized by a number of positive features, as noted in many works:
– practical independence of processing speed, quality, and productivity from the physical and mechanical properties of the materials being processed;
– no need for special tools or abrasives harder than the material being processed;
– a significant reduction in material consumption;
– the relative simplicity of the technology;
– the possibility of local processing of large-sized products without the use of special large machines;
– the prospect of full mechanization and automation;
– high productivity and cost-effectiveness, and reduced processing time.

But despite the positive aspects, EDM has not been widely used in industry because:
– not studying the impact of surface quality on the performance of parts;
– internal tensions may arise;
– it is impossible to control the surface quality to obtain characteristics in a given ratio.

Due to all the above disadvantages of EDM, it is used in industry only for preliminary (rough) machining.

The most widely used method for strengthening the metal surface is the electro-pulse method of electrical discharge machining, as it has the best technical and economic indicators [8].

Research and implementation of electrical discharge machining of metals in Ukraine was carried out by: Orzhonikidze Iron and Steel Works, Odesa National Polytechnic University, Kharkiv Polytechnic University, Kharkiv Bearing Plant, and IMESG.

Undoubtedly, the above-mentioned capabilities of electrical discharge machining of metal surfaces distinguish this method from other hardening methods. Despite this, the mechanism, the nature of wear, and the possibility of self-sharpening of the surface of tillage machine working parts hardened by EDM remain unexplored.

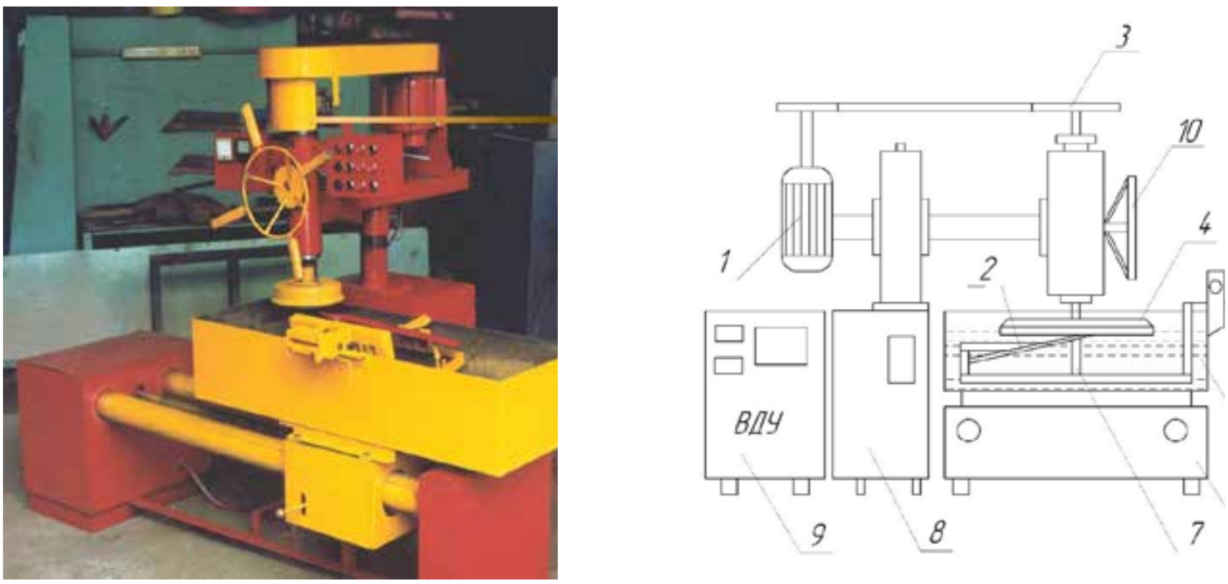
The analysis leads to the solution of *tasks*:
– develop a methodology for conducting laboratory and operational research;
– to experimentally investigate the effect of technological parameters of electrical discharge machining on the wear resistance of samples and working bodies of tillage machines;
– to conduct comparative operational studies of serial and reinforced tillage tools.

The object of research is the process of forming coatings on steels to increase the wear resistance of tillage machines.

The subject of the study is the regularities of the formation of coatings with specified tribotechnical characteristics.

The purpose of the study was to determine the effect of technological parameters of the method of electrical discharge machining, such as current strength, arc voltage, coolant temperature on the relative wear resistance.

The study was conducted on samples of 65Г steel, 45 steel, and X12 steel. The EDM was performed on the 01.10.016A unit (Fig. 2).



a) b)

Fig. 2. General view (a) and schematic diagram (b) of the installation for EDM 01.10.016A:
1 – electric motor; 2 – workpiece; 3 – belt drive; 4 – electrode-tool; 5 – bath; 6 – bath drive; 7 – bed;
8 – control cabinet; 9 – power supply; 10 – control flywheel

The hardened layer is obtained by melting the metal of the workpiece at the point of contact and taking it into the bath. The heated surface of the workpiece cools quickly due to the dielectric medium, hardening to a hardness of HRC 40–65.

The distribution of microhardness along the depth of the treated layer was studied at four points at a distance of 5, 10, 15, and 20 mm from the end of the treatment. The riveted layer formed by cutting the samples was removed by deep chemical etching. The surface hardness was determined using a portable hardness tester T-UD2 (Fig. 3). Hardness measurements were performed in accordance with ASTM A1038. This method is most suitable for controlling the hardness of hardened surface layers, since the depth of penetration of the index is usually in the range of 30–50 μm.

Fig. 3. Hardness tester T-UD2

The microstructure of the steel surface after EDM treatment was studied using a Neophot-32 microscope. Observations were made using the method of light and dark fields in polarized light, with a change in magnification.

To test steel samples hardened by EDM for wear resistance, taking into account technological limitations regarding the possibility of EDM and the need to simulate real wear conditions of working bodies, we used installation of the "impeller" type (Fig. 4).

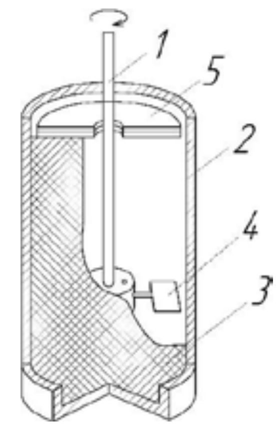


Fig. 4. Scheme of testing by the improved "impeller" method: 1 – shaft holding the samples; 2 – cylinder; 3 – abrasive mass; 4 – samples; 5 – multi-sectional disk that creates the required density of the abrasive mass

The test specimens were made of X12 steel, 65Г steel, and 45 steel. The size of the prototype (Fig. 5) was 70 × 70 × 6 mm.

The inclination of the samples to the plane of rotation was 17 º, which intensifies the wear process and promotes mixing of the abrasive medium. The abrasive mass changed after each sample traveled 100 km.

The shaft-holder (Fig. 6) was driven by the spindle of the vertical boring machine 2E78P (Fig. 7), which allows changing the sample speed from 15,5 to 715,9 m/min (from 0,26 to 11,94 m/s).

The mass wear of the sample was determined on a laboratory balance CP 34001 S by Sartorius (Germany).

The friction path was assumed to be 500 km. During this path, the sample was monitored for weight loss 5 times, or every 100 km. The following factors were taken as constant: travel speed – 125,28 m/min (7,5 km/h); soil pressure on the sample – 1,25 kG/cm^2 (122,6 kPa). Quartz sand with a fraction size of 80–100 microns was used as a working medium.

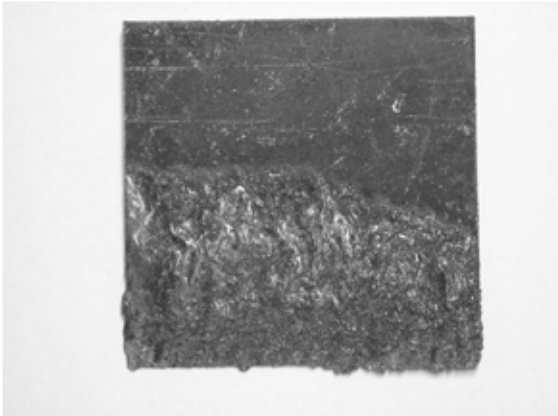


Fig. 5. General view of the prototype

Fig. 6. Shaft holder with prototypes: 1 – prototype; 2 – shaft holder; 3 – 2E78P machine

The following was proposed as an optimization criterion in the study: σW – wear resistance, km/h.

Fig. 7. General view of the wear test setup

The research factors are: 1. Current strength, A; 2. Current voltage, V; 3. Temperature of the cooling (dielectric) medium, ºC.

The choice of the experimental area of the factor space was made taking into account the a priori information that the best conditions for the process of EDM are those that are achieved.

To confirm the validity of the experiment, the factors were changed at 2 levels. In order to describe the mathematical model, a Box-Benken experiment was planned.

Operational studies of reinforced and serial working bodies of disk tillage tools were conducted during 2023–2024 at Starokotelnyanske LLC, Andrushiv district, Zhytomyr region, using universal disk units УДА-4.5.

In order to optimize the technological parameters of the EDM process, a multifactorial active experiment of type 2^3 was conducted, in which the influence of technological parameters of EDM on the wear resistance of the treated surface was studied. The experimental data obtained were processed using the application programs Microsof Excel and Maple 14 on a PC. As a result of the study, the regression equation was obtained in a decoded form:

– for 65Г steel:

$$\begin{gathered}\sigma_W = -485{,}97 + 0{,}912I + 17{,}2U_B + 0{,}444t_C - 0{,}00066IU_B - \\ -0{,}000078It_C + 0{,}0041U_Bt_C - 0{,}0012I^2 - 0{,}194U_B^2 - 0{,}0099t_C^2\end{gathered}; \quad (1)$$

– for X12 steel:

$$\begin{gathered}\sigma_W = -825{,}32 + 1{,}852I + 27{,}561U_B + 1{,}056t_C - 0{,}002IU_B + \\ +0{,}00007It_C + 0{,}003U_Bt_C - 0{,}002I^2 - 0{,}306U_B^2 - 0{,}019t_C^2\end{gathered}; \quad (2)$$

– for steel 45:

$$\begin{gathered}\sigma_W = -368{,}2 + 0{,}61I + 13{,}7U_B + 0{,}08t_C - 0{,}00028IU_B + \\ +0{,}00019It_C + 0{,}0075U_Bt_C - 0{,}00085I^2 - 0{,}16U_B^2 - 0{,}0079t_C^2\end{gathered}; \quad (3)$$

When analyzing the equations for determining the zone of extremes, the regression equations were differentiated by the variable factors and the resulting expressions were set to zero. By solving these systems, the values of the factors at the point of optimum were obtained:

– for 65Г steel:

$I = 374$ A, $U_V = 44{,}1$ V, $t_C = 30$ °C, wear resistance was $\sigma_W = 66{,}57$ km/h;

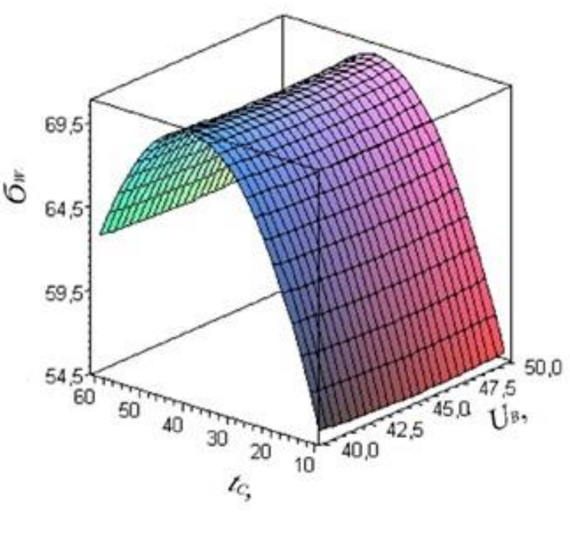
– for X12 steel:

$I = 375{,}5$ A, $U_V = 43{,}85$, V, $t_C = 30{,}5$°C, wear resistance was $\sigma_W = 143{,}07$ km/h;

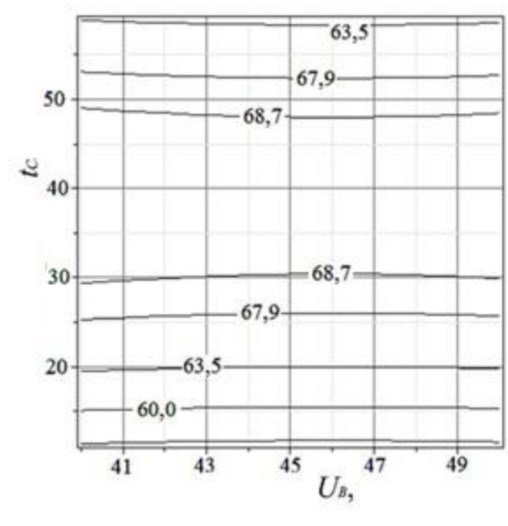
– for steel 45:

$I = 372{,}5$ A, $U_V = 44{,}2$, V, $t_C = 30{,}5$ °C, wear resistance was $\sigma_W = 46{,}01$ km/h.

For further study of the mathematical model, we used the method of two-dimensional sections, which resulted in the following: a) response surfaces and contour plots of the effect of voltage and temperature of the cooling medium on wear resistance (Fig. 8); b) response surfaces and contour plots of the effect of current and temperature of the cooling medium on wear resistance (Fig. 9); c) response surfaces and contour plots of the effect of current and voltage on wear resistance (Fig. 10).



a)

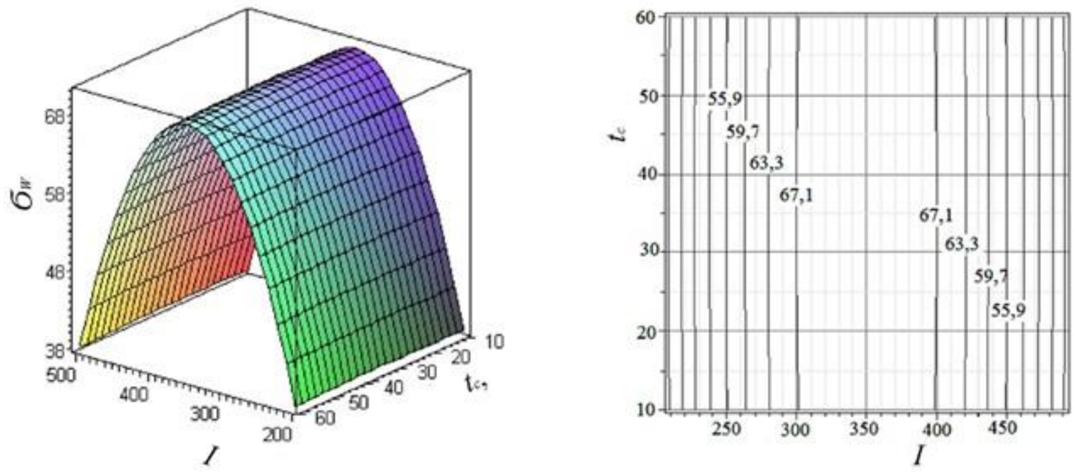


b)

Fig. 8. Response surface (a) and contour graph (b) of the effect of stress and temperature of the cooling medium on the wear resistance of 65Г steel

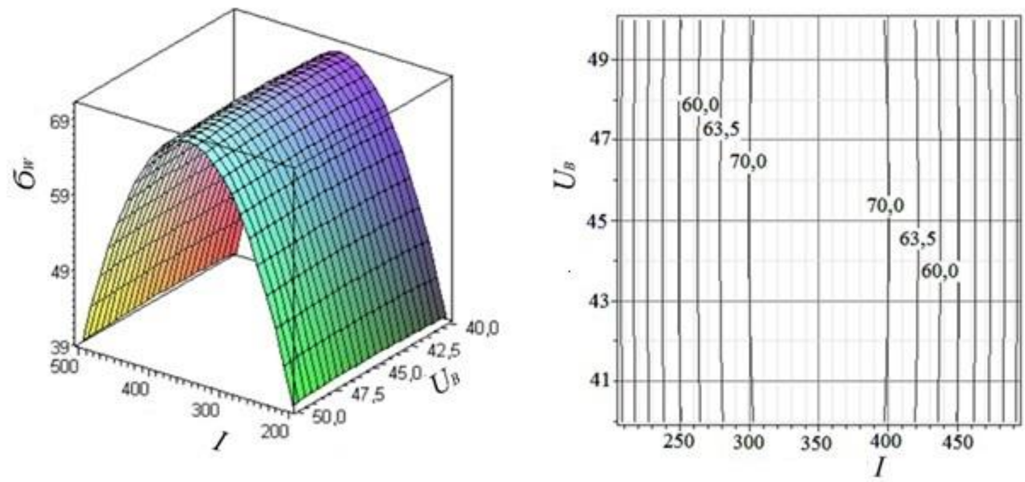
Analyzing the results obtained, we can conclude that regardless of the steel grade, the rational modes of EDM are: current 350–450 A, voltage 45 V, dielectric medium temperature 30–40 °C.

From the presented graphs (Figs. 8–10), it can be seen that the most significant effect on the wear resistance of the treated surface is the current strength, since the quality of the melting of the surface layer and the depth of EDM depend on it. Another significant factor is the temperature of the dielectric cooling medium: with an increase in the temperature of the cooling medium, the surface cooling rate cannot satisfy the conditions (200 °C/s) for the formation of martensitic structures, and with a decrease in temperature, internal stresses arise in the hardened surface, which lead to the formation of microcracks.



a) b)

Fig. 9. Response surface (a) and contour plot (b) of the effect of current strength and coolant temperature on the wear resistance of 65Гsteel



a) b)

Fig. 10. Response surface (a) and contour plot (b) of the effect of current and voltage on the wear resistance of 65Г steel

Taking into account previous studies of the influence of technological indicators of EDM on the hardness and wear resistance of steel, the samples were hardened at the following conditions specified in Section 4.1: current 450 A; voltage 45 V; temperature of the working medium (water) 35 °C.

In the course of the study, the dependence of the microhardness distribution on the depth of the hardened layer after EDM was established.

The obtained results make it possible to conclude that, under EDM, the microhardness of the surface layer of steel X12 increases to 12–12,8 GPa, steel 65Г – to 10,5–11,2 GPa, steel 45 – to 7,3–8,2 GPa. Such surface hardness makes micro-cutting processes impossible (under normal operating conditions) during abrasive wear of the working bodies of tillage tools, so the microhardness of the most abrasive mineral that is part of the soil (quartz) is 9,8–12,7 GPa.

Surface hardness is not always the main indicator of a metal's wear resistance; its chemical composition and structure have a significant impact on its wear resistance.

Changes in the chemical composition of the studied steels are typical, so it can be argued that regardless of the steel grade, during the process of EDM treatment on the installation 01.10.016A, the surface layer is saturated with such chemical elements as Mn, Si, S, Ni, Cr, and the content of Cu, P decreases.

Studies of structural transformations have shown that as a result of EDM, a wear-resistant layer with a fine martensitic structure is formed (Fig. 11), regardless of the operating conditions. This is due to the fact that the study was carried out at a working medium (water) temperature in the range of 20–60°C, and this temperature provides cooling of the treated surface at a rate of more than 200 °C/s, which is necessary for the formation of martensitic structures. During EDM, a high adhesion strength of the alloyed layer with the base material is formed, i.e., a high adhesion strength of the hardened layer with the base.

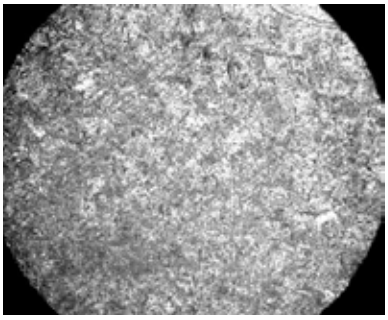


Fig. 11. Cross-sectional structure of a 65Г steel sample after electrical discharge machining

As a result of the study of the wear of the disks of the universal disk unit УДА, it was found that the wear resistance of the disks does not differ significantly for each group, even though these disks have some design differences (tooth shape) (Fig. 12).

Fig. 13 shows a diagram of the operating time to the limit state of disks made of different materials and with different methods of hardening.

Fig. 12. Types of teeth used in the study

As can be seen from this diagram, the discs made of 65Г steel and hardened by EDM with simultaneous sharpening (30º sharpening angle) have the highest wear resistance.

The revealed wear patterns of hardened and serialized working tools support the friction surfaces (Fig. 14).

The hardened areas have a relatively flat surface (Fig. 14), and the non-hardened area of the tooth is covered with small scratches. Based on the above, it can be concluded that in the process of abrasive wear on the surface after electrical discharge machining, there is no process of microcutting by abrasive particles, but a polishing effect is observed, this phenomenon indicates the superiority of plastic deformation over other components of abrasive wear.

Conclusions. The rational modes of electrical discharge machining of steels are: current 350–450 A, voltage 45 V, temperature of the dielectric (working) medium 30–40 °C, which made it possible to obtain wear resistance: for 65Г steel – 66,57 km/h, for X12 steel – 143,07 km/h, for 45 steel – 46,01 km/h.

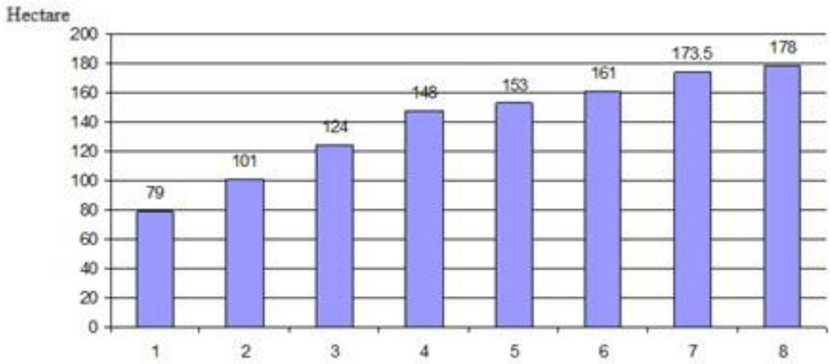


Fig. 13. Operating time of disks to the limit state: 1 – serial disks made of steel 45; 2 – serial disks made of steel 65Г; 3 – disks made of steel 65Г with bulk hardening of 810–830 °C and medium tempering with very precise holding at a temperature of 460–480 °C; 4 – disks made of X12 steel; 5 – serial disks made of 28MnB5 steel; 6 – disks made of 65Г steel and hardened by EDM method with simultaneous sharpening (sharpening angle 17 º); 7 – disks made of 65Г steel and hardened by T-590 electrode; 8 – disks made of 65Г steel and hardened by EDM method with simultaneous sharpening (sharpening angle 30 º)

Fig. 14. Typical view of the friction surface of the working body hardened by EDM

Regardless of the steel grade, the microhardness of the layer after EDM treatment is maximum on the surface (for X12 steel – 12–12,8 GPa, 65Г steel – 10,5–11,2 GPa, 45 steel – 7,3–8,2 GPa) and gradually decreases as it deepens, and turns into the microhardness of the base, which makes it possible to use this method of hardening to increase the wear resistance of tillage machine parts.

The surface layer after electrical discharge machining is saturated with such chemical elements as Mn, Si, S, Ni, Cr, and the content of Cu, P decreases, which contributes to the surface layer with improved physical and mechanical properties.

As a result of electrical discharge machining, a fine martensitic structure is formed in the treated layer, which contributes to increased wear resistance.

After conducting operational studies, it was found that the wear resistance of tillage machine working bodies hardened by electrical discharge machining is 1,76 times higher than that of serial ones. During operation, such disks exhibit the effect of self-sharpening, and the coefficient of shape change remains almost unchanged throughout the entire period of operation.

Prospects for further research. In further research, it is advisable to focus on the comprehensive optimization of the parameters of electrical discharge machining, taking into account the specifics of the alloys used to manufacture the working bodies of tillage machines. It is equally important to study the effect of working medium modifiers (powder additives, nanocomposites) on the stability of erosion discharges and the homogeneity of the treated layer. At the same time, it is necessary to conduct an economic and environmental analysis to assess the feasibility of scaling the process for mass production in terms of energy consumption, resource conservation, and minimization of harmful emissions. In addition, it is worth considering the possibility of integrating electrical discharge machining with other hardening technologies (e.g., laser or ion plasma), which will open up new combinations of surface properties.

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ПІДВИЩЕННЯ ЗНОСОСТІЙКОСТІ РОБОЧИХ ОРГАНІВ ҐРУНТООБРОБНИХ МАШИН МЕТОДОМ ЕЛЕКТРОЕРОЗІЙНОЇ ОБРОБКИ

Анотація

У роботі встановлено ефективні технологічні параметри електроерозійної обробки для підвищення зносостійкості сталей, які працюють в умовах абразивного зношування. Установлено, що оптимальними технологічними параметрами електроерозійної обробки є: сила струму – 350–450 А, напруга – 45 В, температура робочого середовища – 30–40 °С. За результатами проведених досліджень установлено, що найбільш суттєво на зносостійкість обробленої поверхні впливає сила струму, оскільки від неї залежать якість розплавлення поверхневого шару та глибина обробки. Також суттєвим чинником є температура діелектричного охолоджувального середовища: у разі збільшення температури охолоджувального середовища швидкість охолодження поверхні не може задовольнити умови (200 °С/с) утворення мартенситних структур, а в разі зменшення температури у зміцненій поверхні виникають внутрішні напруження, які призводять до утворення мікротріщин. У результаті електроерозійної обробки мікротвердість обробленого шару підвищується для сталі Х12 у межах 12–12,8 ГПа, для сталі 65Г у межах 10,5–11,2 ГПа, для сталі 45 у межах до 7,3–8,2 ГПа. Підвищення твердості відбувається завдяки формуванню дрібноголчастої структури мартенситу та легування поверхневого шару Mn, Si, Ni та Cr.

Установлено, що використання електроерозійної обробки підвищує зносостійкість сталі 65Г за експлуатації на різних за механічним складом ґрунтах, з відмінними властивостями абразивного середовища та різними зовнішніми чинниками в середньому на 60–80%.

Застосування електроерозійної обробки для зміцнення робочих органів дискових ґрунтообробних знарядь, виготовлених зі сталі 65Г, дозволяє підвищити зносостійкість порівняно із серійними – в 1,76 раза, з робочою поверхнею, зміцненою електродом Т-590, – в 1,1 раза, з робочими органами фірми "Bellota" (виготовлених зі сталі 28MnB5) – в 1,16 раза. Окрім того, під час експлуатації робочих органів, зміцнених електроерозійною обробкою, спостерігався ефект самозагострювання, що сприяло зменшенню тягового опору на 4–16% порівняно із серійними.

Ключові слова: *сталь, твердість, електроерозійна обробка, зносостійкість.*

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